Polarized Source Performance and Developments at Jefferson Lab

M. Poelker, P. Adderley, J. Clark, A. Day, J. Grames, J. Hansknecht, P. Hartmann, R. Kazimi, P. Rutt, C. Sinclair, M. Steigerwald

Thomas Jefferson National Accelerator Facility
12000 Jefferson Ave., Newport News, VA 23606, USA

Abstract. The polarized photoinjector at Jefferson Lab continues to provide high average current, high polarization, high quality beam to nuclear physics Users in as many as three endstations simultaneously. Long lifetime operation has been obtained from two identical polarized guns. A new high power modelocked ti-sapphire laser has been constructed to enhance the effective operating lifetime of the photoinjector. Efforts to enhance beam polarization and reduce helicity correlated beam systematic effects are underway.

INTRODUCTION

Jefferson Lab is a cw electron accelerator with a recirculating linac design and beam energies to 6 GeV. There are three endstations and each can receive beam simultaneously. The beam current requirements in each hall vary significantly; Halls A and C can take up to 120 microA, Hall B typically receives only 1 to 4 nanoA. Multiple simultaneous Users and a large dynamic current range place strict demands on the photoinjector and laser systems.

The polarized beam program at Jefferson Lab began in December, 1997 with bulk GaAs and a peggy-style polarized electron gun. Performance was greatly enhanced when the gun was modified to accommodate improved pumping near the cathode/anode gap and other features described below [1]. Only high polarization photocathodes have been used since August, 1998. The most recent injector modification occurred during the summer of 1999 when the photoinjector was rebuilt to house two identical polarized guns, one in use for production beam delivery and one serves as a spare.

Gun performance improved significantly when non-evaporable getter (NEG) pumps were installed near the photocathode to provide more than 2000 L/s pump speed and a base pressure in the main gun chamber in the upper 10e-12 Torr range (Figure 1). But central to the success of the new gun design was the realization that during operation, a small portion of the total photoemitted gun current originates from the edge of the photocathode, beyond the region where the photocathode is directly illuminated with laser light. Photomission from large radius of the photocathode is probably a result of low level ambient light within the gun caused by stray laser light or spontaneous

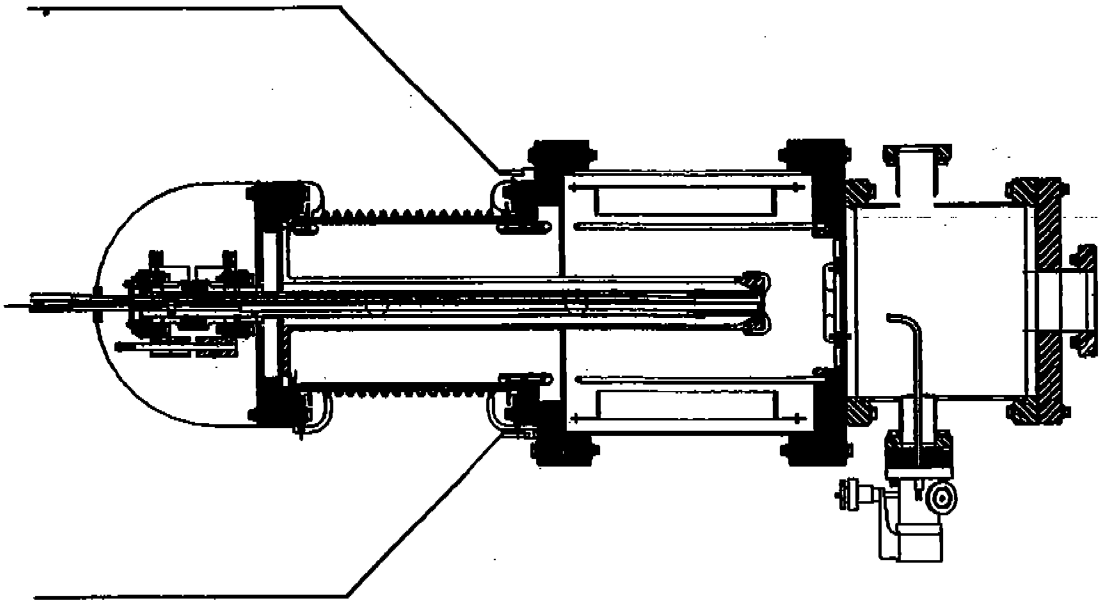

FIGURE 1. Schematic diagram of the Jefferson Lab polarized electron gun. There are two such guns installed in the photoinjector, one for production beam delivery and one spare available when necessary.

emission from the photocathode itself. Electrons that originate from the edge of the photocathode follow extreme trajectories; some hit the anode plate, some travel further from the gun and hit beamline walls, situations that degrade vacuum pressure through stimulated desorption of gas and subsequent quantum efficiency degradation via ion backbombardment. The following precautions reduce the production of photoemission from large radius of the photocathode and help minimize deleterious effects should the circumstance persist; a) the edge of the photocathode wafer is anodized [2] to produce quantum efficiency of zero at large radius, b) large diameter vacuum beamline tubes (2.5 inch) are coated with NEG material to minimize electron stimulated desorption and provide improved pumping near the source of the gas source should electrons strike the beamline walls [3], and c) the short focal length electron optical elements of previous injector configurations (90 degree bend magnet and electrostatic bends of the z-style spin manipulator) were replaced with a 15 degree bend magnet and Wien-style spin manipulator.

The effectiveness of these features is illustrated by considering photoinjector performance during a recent 6 month period from January through June, 2000. During this period over 900 Coulombs were extracted, with approximately 2/3 delivered to the endstations. The average charge lifetime from both guns approached 200 Coulombs, where lifetime refers to the total charge extracted until the quantum efficiency falls to 1/e of the initial value. Ion backbombardment is the sole mechanism by which quantum efficiency degrades. The effective operating lifetime of the gun exceeds the charge lifetime because quantum efficiency degrades only at the location of laser spot and along a line radially inward to the electrostatic center of the cathode. The laser beam diameter (0.5 mm) is considerably smaller than the active area of the photocathode (6 mm) so it is possible to continue delivering beam to the endstations by moving the laser to fresh locations on the photocathode. The effective operating lifetime of the gun is also enhanced by occasional recesiations or heat treatment followed by full reactivations with cesium and nitrogen trifloride. Quantum efficiency degradation from ion backbombardment is completely restored following a heat treatment.

LASER SYSTEMS

Until very recently, only diode laser systems [4] were used to drive the Jefferson Lab photoinjector. The diode laser systems are composed of gain-switched diode seed lasers and diode optical amplifiers. Optical pulsewidths of ~ 50 ps are obtained with approximately 100mW average power at a pulse repetition rate of 499 MHz and 250mW at 1497 MHz. The diode laser systems have many appealing features including relatively low cost (~ 15K USD) and near maintenance-free, long lifetime operation. The laser output is "clean" with low amplitude noise and pulse-to-pulse timing jitter. The most appealing feature of the diode laser system is the ease by which the optical pulse train can be phase locked to the accelerator. This is because the pulse forming mechanism, gain switching, is independent of the diode laser cavity length. The pulse repetition rate and the phase of the optical output follows that of the sinusoidal rf signal applied to the diode seed laser.

Unfortunately, there are disadvantages of the diode laser systems. In particular, the relatively low output power of the systems (and the low quantum efficiency of strained layer photocathodes) makes it difficult to meet the high current beam requirements of the nuclear physics community. In addition, the manufacturer of the diode optical amplifier (Spectra Diode Labs) no longer sells this component and other vendors are unknown. Finally, the diode laser systems do not provide extensive wavelength tunability (only +/- 5 nm via temperature tuning) and as a result, new photocathodes may require completely new diode elements to reach the wavelength that provides peak polarization.

To overcome the limitations of the diode laser systems, a novel modelocked ti-sapphire laser has been constructed [5] and installed in the injector. The complete laser system composed of the new ti-sapphire laser and diode laser systems is shown in Figure 2. Diode laser systems continue to provide high-polarization beam to endstations that require < 30 microA. The ti-sapphire laser is used for endstations with higher beam current requirements

The ti-sapphire laser cavity has a double-fold geometry and is pumped with green light from a solid-state Verdi-10 laser (Coherent Inc.). The ti-sapphire laser can be configured with one or two output coupler mirrors; one output coupler mirror for high current beam delivery to one hall, and two output coupler mirrors when two halls require simultaneous high current beam. The cavity length is chosen to be 60.1 cm corresponding to a longitudinal mode spacing of 249.5 MHz, a subharmonic of the

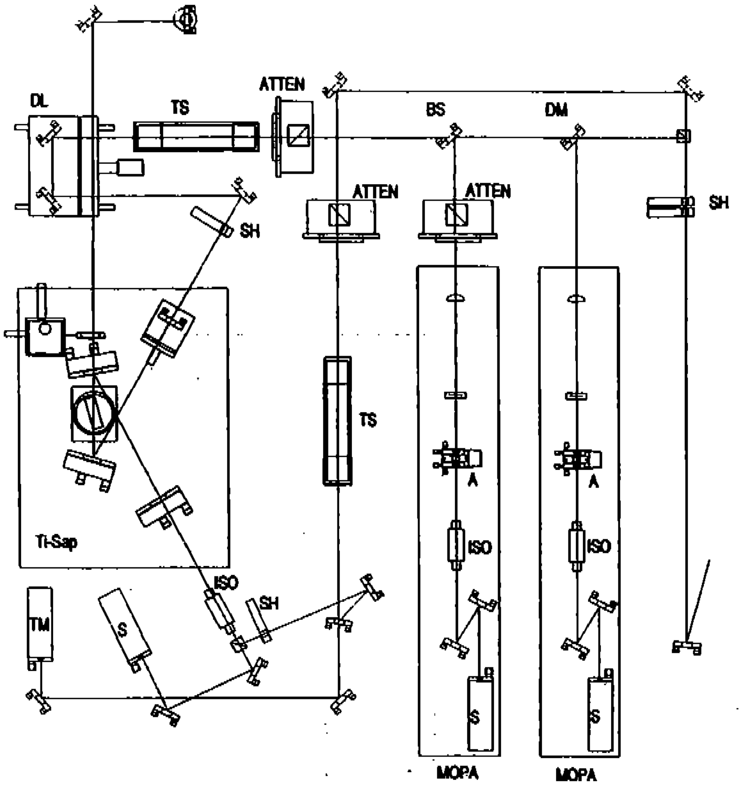

FIGURE 2. Schematic diagram of the Jefferson Lab drive laser system. MOPA, diode laser system; S, gain-switched diode laser; A, diode amplifier; ISO, optical isolator; Atten, optical attenuator; TS, telescope; SH, shutter; DM, dichroic mirror; BS, beamsplitter; DL, optical delay line; TM, tune mode laser diode.

accelerator cavity rf frequency. Modelocked pulsed operation of the ti-sapphire laser is obtained when light from a gain-switched diode laser is directed into the cavity and the repetition rate is set to 499 MHz. The best optical pulses (i.e., most stable) are obtained when the ti-sapphire and diode laser wavelengths are equal to within a few nanometers. The phase of the ti-sapphire laser optical pulse train is set by the phase of the rf signal used to drive the gain-switched diode laser, a situation that makes it a simple matter to lock the optical pulse train to the accelerator. Presently, the cumulative output power of the laser is ~ 800 mW with pump power of 5 W. The laser has been running nearly continuously at Jefferson Lab for approximately three months and although this laser requires more attention than diode laser systems, performance has been very good. Occasional mirror cleaning and adjustment of mirror alignment and cavity length are necessary to maintain optimum output power and pulse stability. In the future, feedback mechanisms will be implemented to reduce the necessity of making these occasional manual laser adjustments. Currently, experiments in two endstations receive 60 microA of high polarization beam using the ti-sapphire drive laser. The high power capability of this laser provides exceptionally long operating lifetimes, allowing weeks of uninterrupted high current beam delivery before actions must be taken to restore the photocathode quantum efficiency. Laboratory demonstration suggests output powers to 2 W are possible in the future.

ENHANCING BEAM POLARIZATION

To date, we have used only high polarization photocathodes from Spire Inc. (Bandwidth Semiconductor). These GaAs-on-GaAsP photocathodes are grown to the SLAC specification and the best samples have provided beam polarization 70 to 80%. Unfortunately, many samples provide lower beam polarization, and these wafers are rejected for use in the photoinjector. Polarization also varies from location to location across a single sample. Polarization within the 6 mm diameter active area can vary by +/-10%. There is speculation within the polarized source community that low polarization and polarization variation across a small sample may a be result of photocathode surface roughening caused by atomic hydrogen cleaning [6]. All photocathodes at JLAB are cleaned via atomic hydrogen [7] and tests are underway to investigate possible effects on beam polarization.

There is a considerable backlog of nuclear physics experiments awaiting beam time at Jefferson Lab. Higher beam polarization will reduce the amount of time required to achieve appropriate statistical accuracy and thereby hasten the process of conducting nuclear physics research. As such, it is very important to begin using photocathodes that provide polarization greater than 80%. To this end, we are testing photocathode material from the groups of Nakanishi, Terekhov and Mamaev.

REDUCING HELICITY CORRELATED BEAM SYSTEMATICS

During the spring of 1999, a parity violation experiment was conducted in Hall A (HAPPEX) using high polarization beam from a strained layer photocathode [8]. This experiment required control of helicity correlated charge asymmetry to less than one ppm and it was feared that strained layer photocathodes would be unacceptable because of the inherent quantum efficiency anisotropy associated with the presence of residual linearly polarized light in the two helicity states [9]. Fortunately helicity correlated charge asymmetry was kept acceptably small using a rotating halfwave plate downstream of the pockel cell. This device was used to orient the residual linear polarization in directions to produce equal beam current in the two helicity states.

Future nuclear physics experiments however will require more sophistication (i.e., tighter control of helicity correlated charge, position and beam energy asymmetries). Efforts are underway to minimize the problematic nature of strained-layer photocathodes by creating more highly circularly polarized laser light. An ellipsometer is being constructed to help properly orient the pockel cell with high accuracy and reproducibility with the hope that circular polarization of 99.9999% can be obtained. A test stand has been constructed to study the laser beam-steering properties of pockel cells and piezo-driven mirror mounts have been added to the laser table to counter the beam steering effects of the pockel cell. Finally, it may be possible to use Kerr cells rather than pockel cells as a means to eliminate helicity correlated position asymmetries.

ACKNOWLEDGMENTS

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